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**Nishibu et al.**

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(54) **FUEL SUPPLY SYSTEMS**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 509 days.

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**F02M 59/36** (2006.01)

**F16K 31/12** (2006.01)

(52) **U.S. Cl.** ..... **123/458**; 137/510; 137/505.14

(58) **Field of Classification Search** ..... 123/457-465; 137/494, 509, 510, 505, 505.12, 505.14  
See application file for complete search history.

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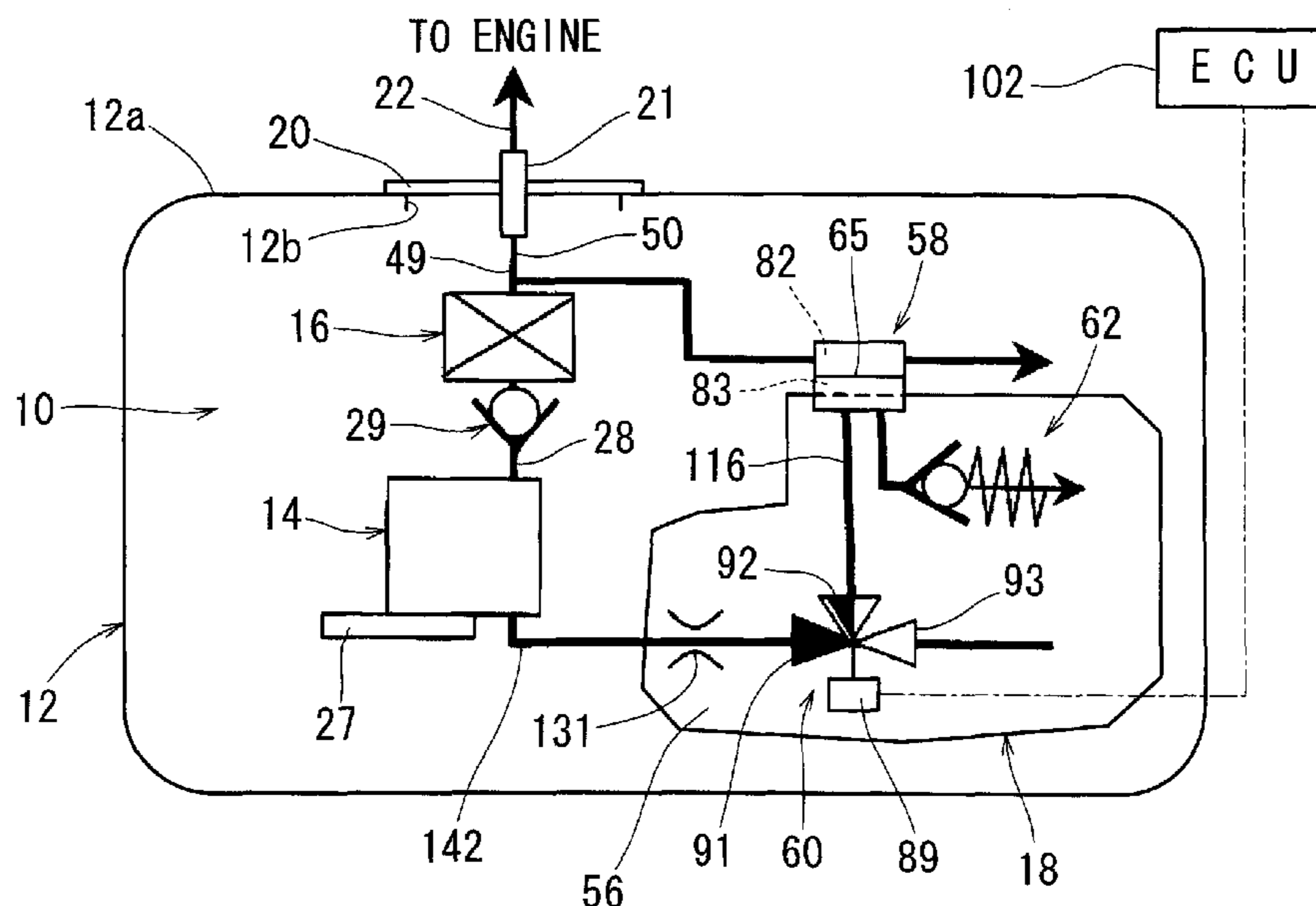
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(57) **ABSTRACT**

A fuel supply system includes a fuel pump for supplying fuel in a fuel tank to an engine, a pressure regulator and a three-way valve disposed in a valve chamber. The pressure regulator includes a pressure regulating chamber and a control pressure chamber and adjusts a fuel pressure in the pressure regulating chamber depending on a fuel pressure in the control pressure chamber. A control pressure passage for flowing the fuel to the control pressure chamber and the valve chamber is formed in a unit case.

**6 Claims, 11 Drawing Sheets**



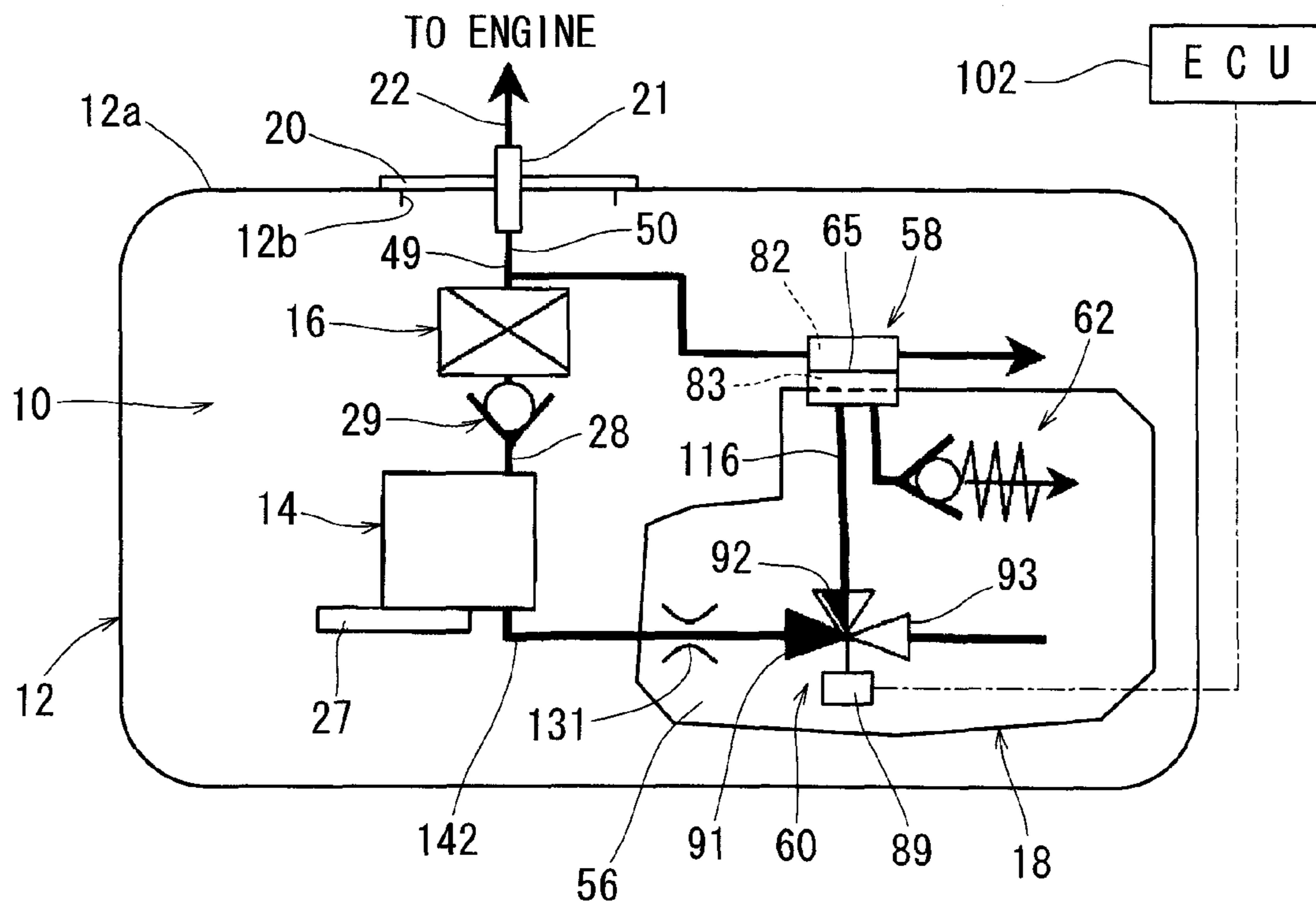
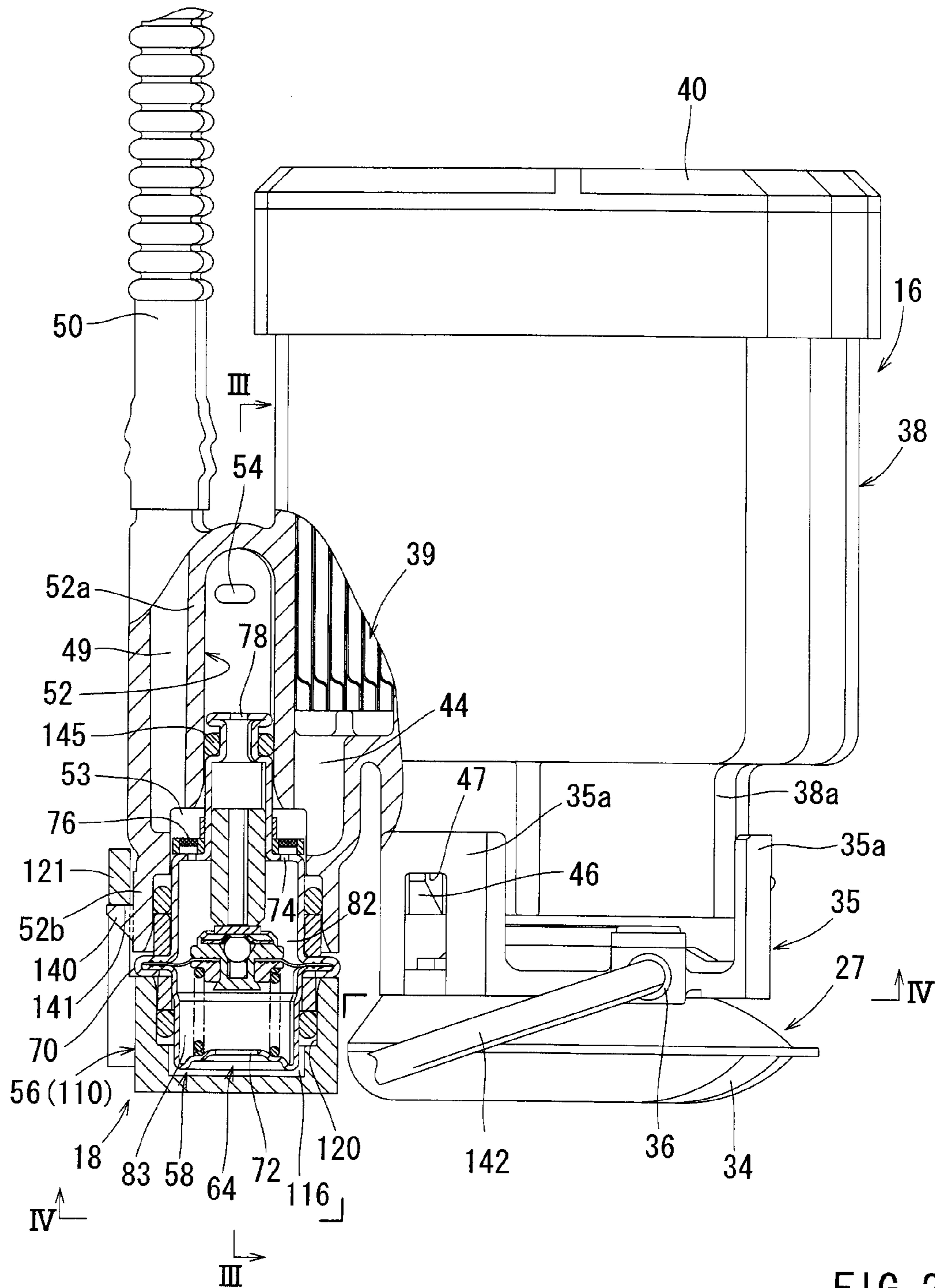


FIG. 1



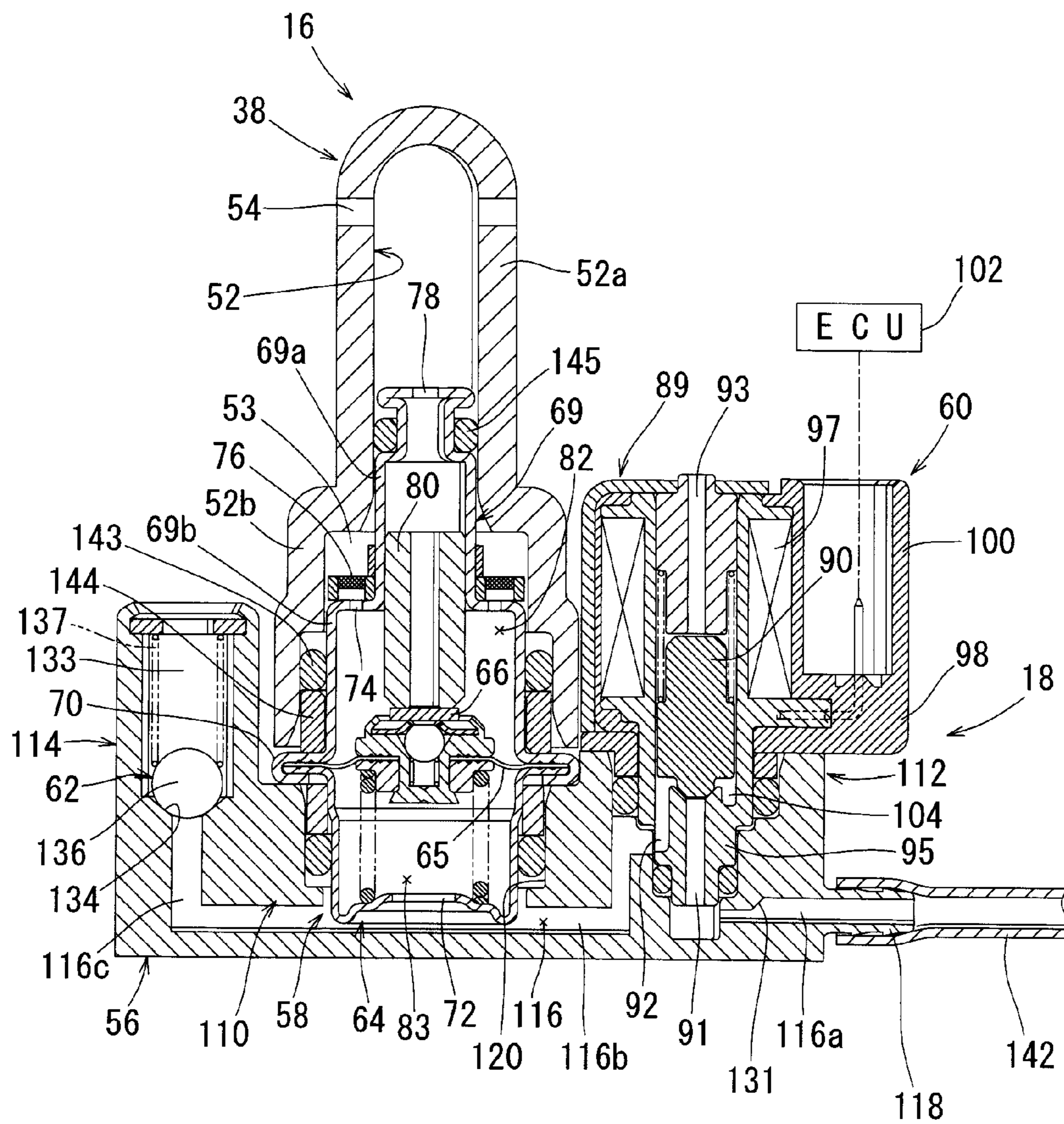


FIG. 3



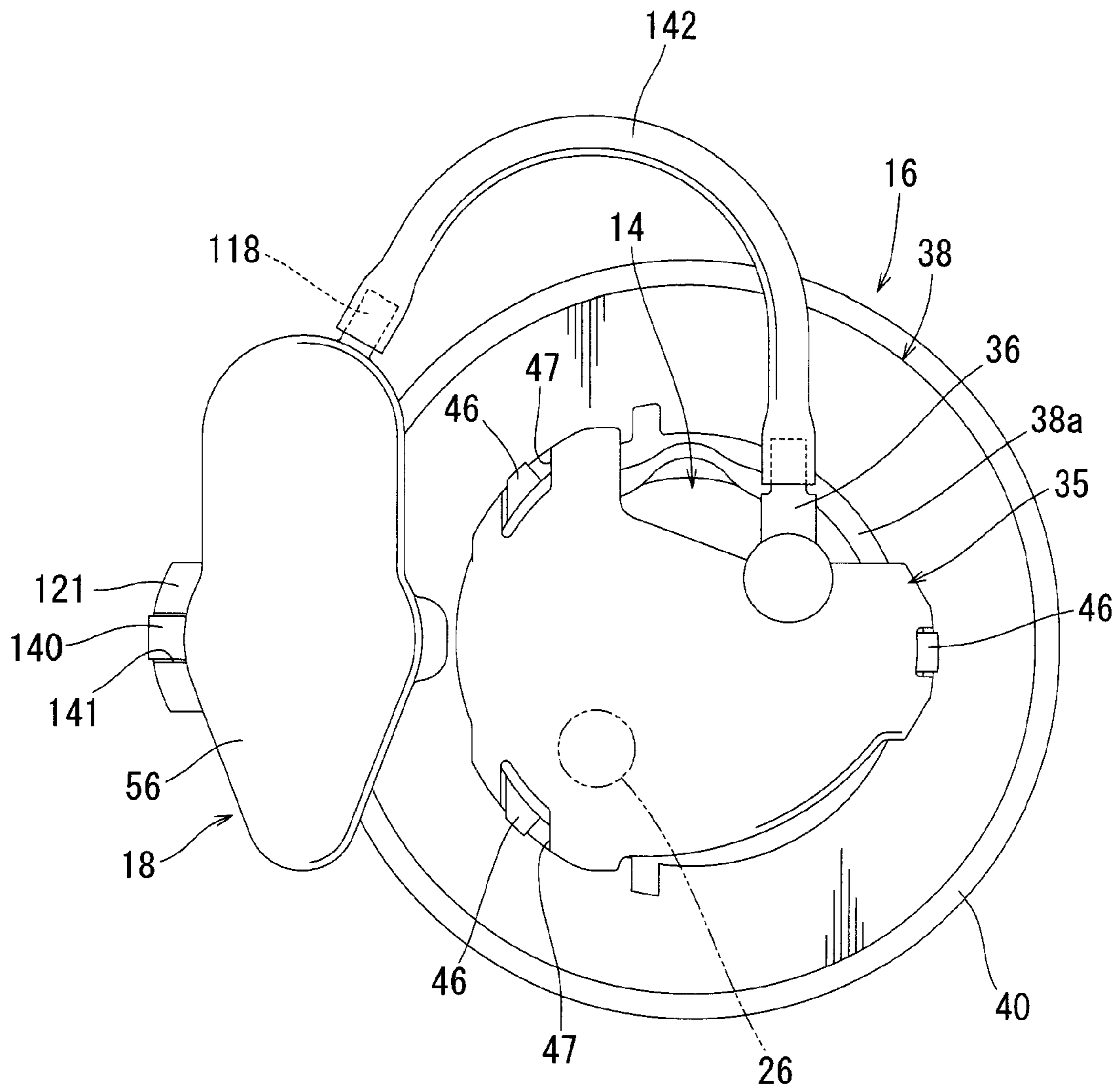


FIG. 4

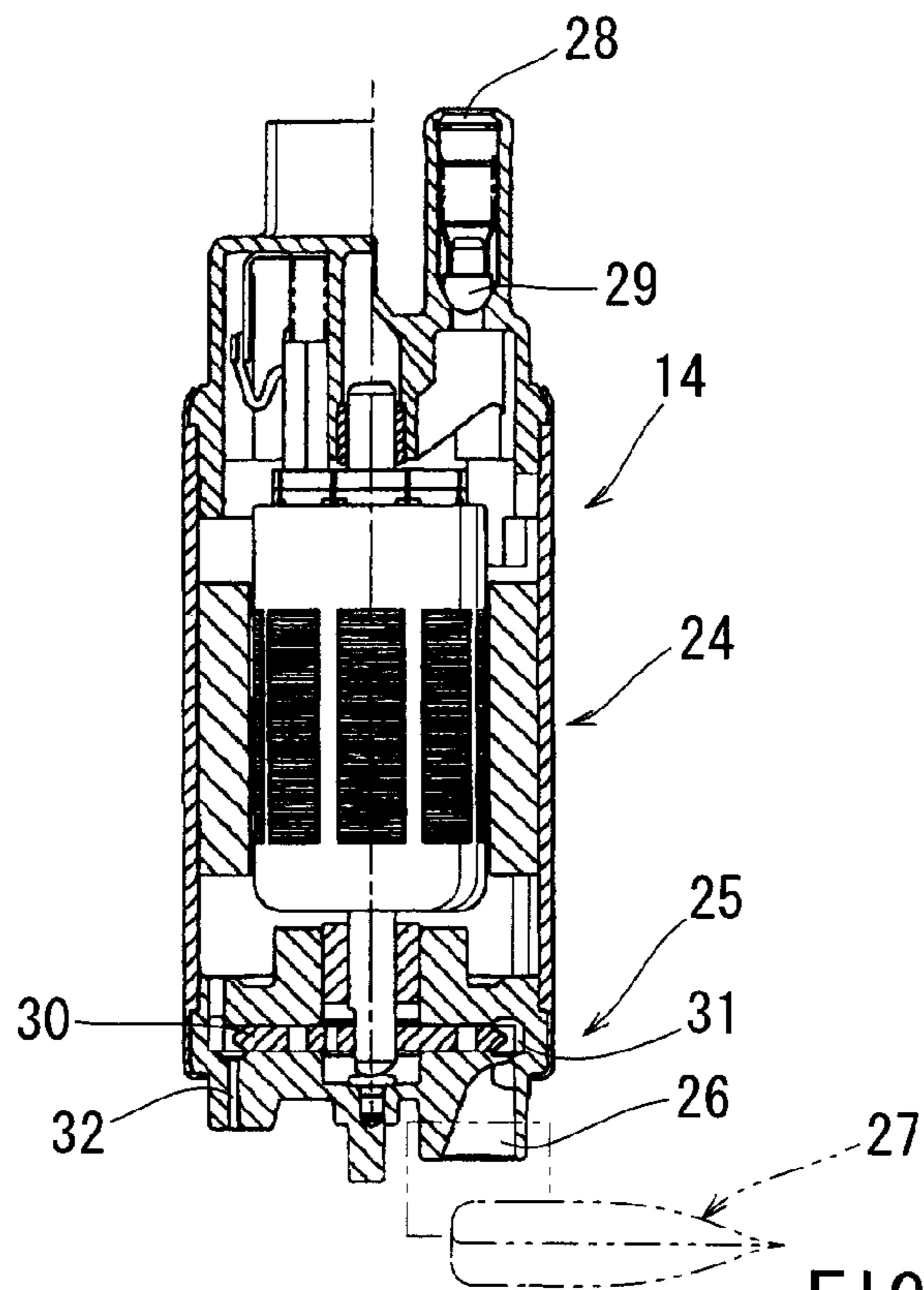


FIG. 5

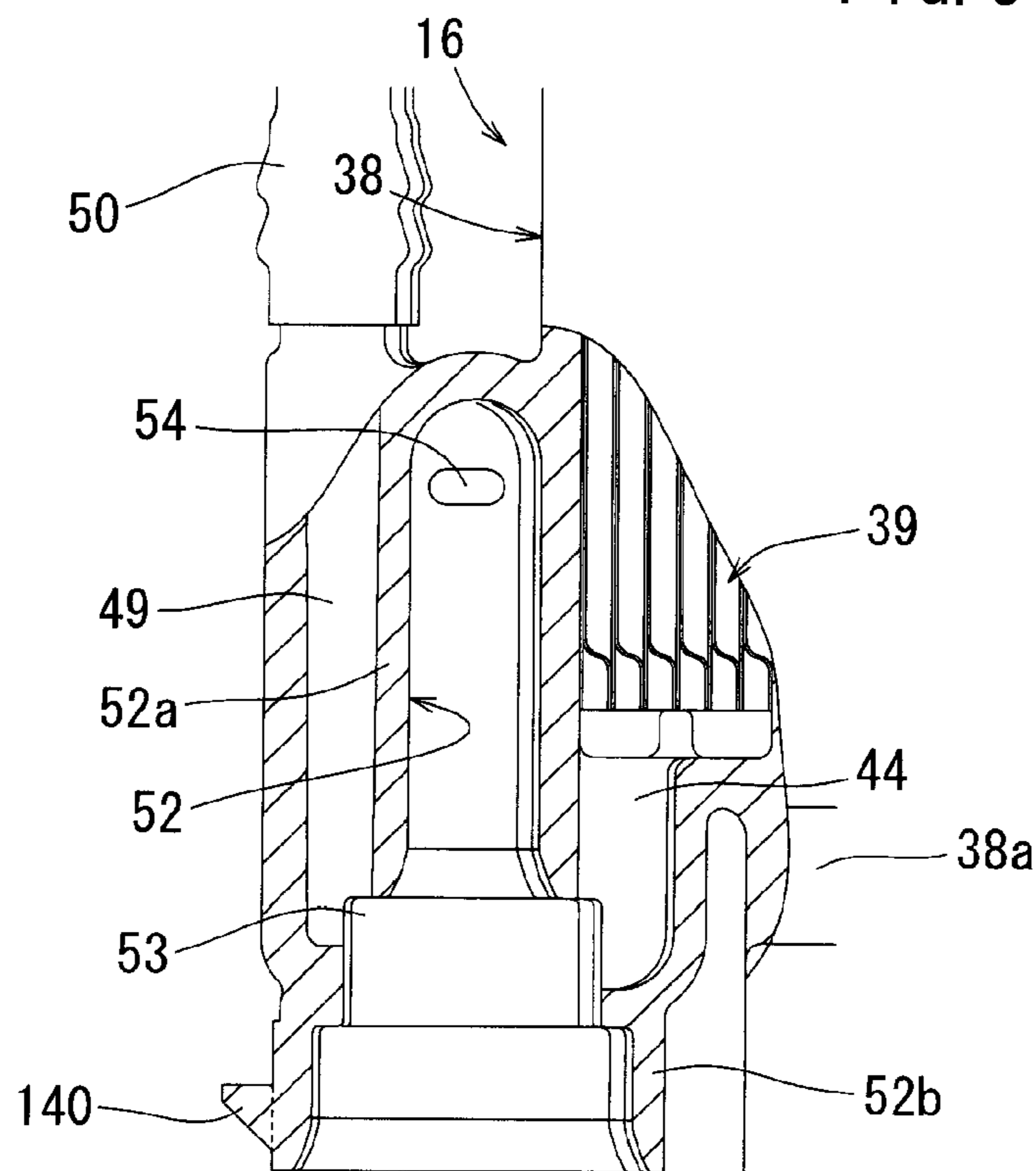


FIG. 6

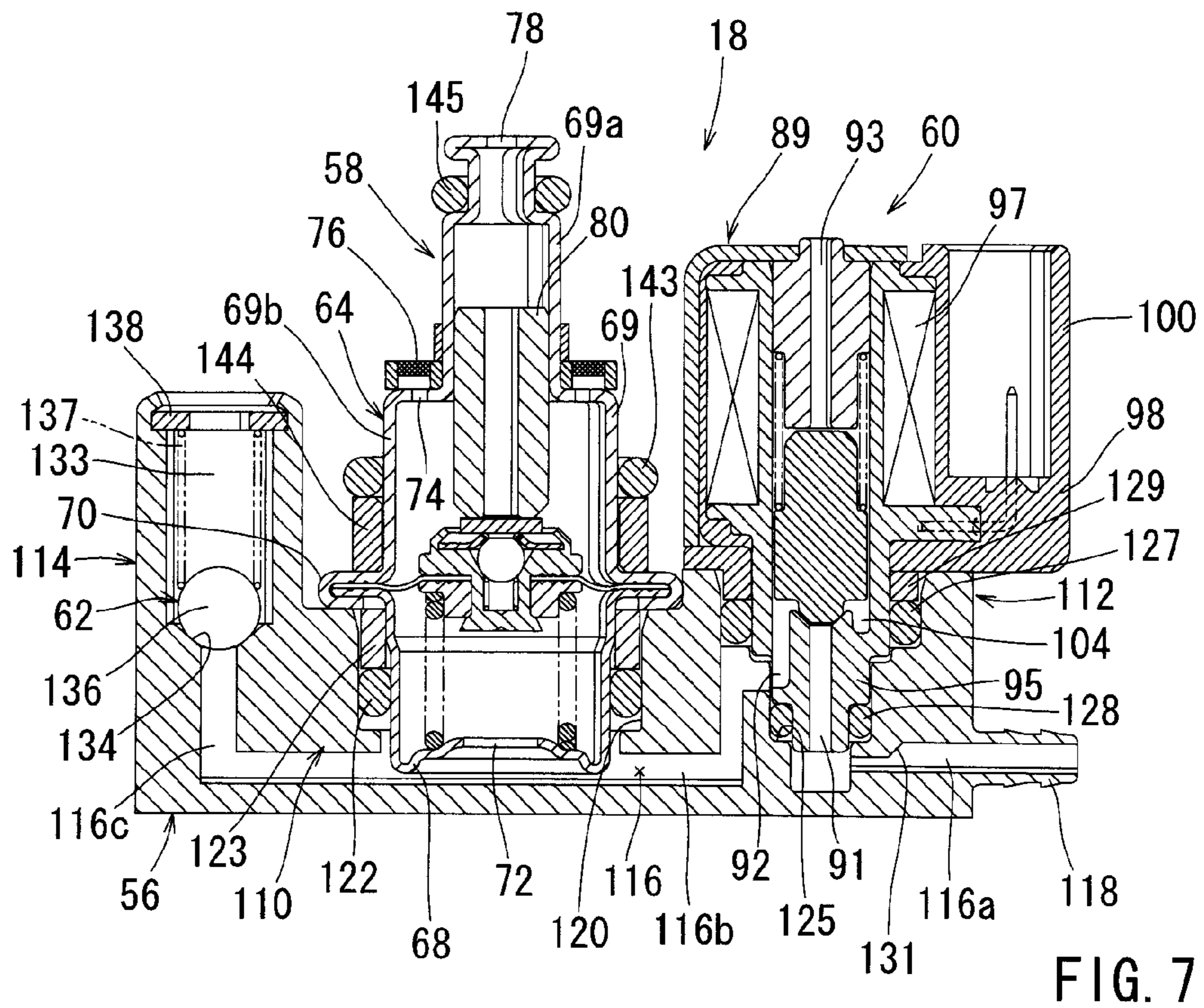


FIG. 7

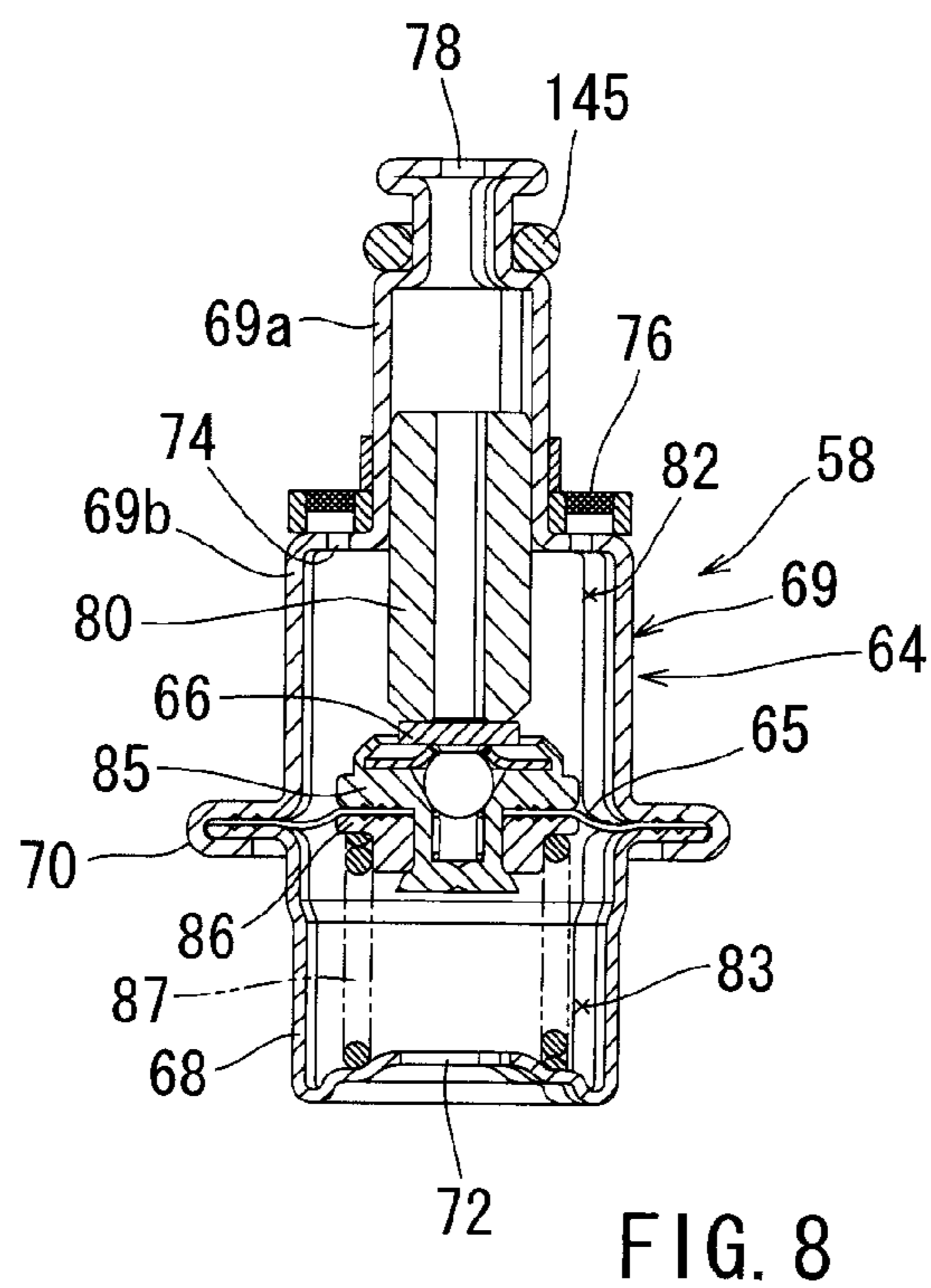


FIG. 8

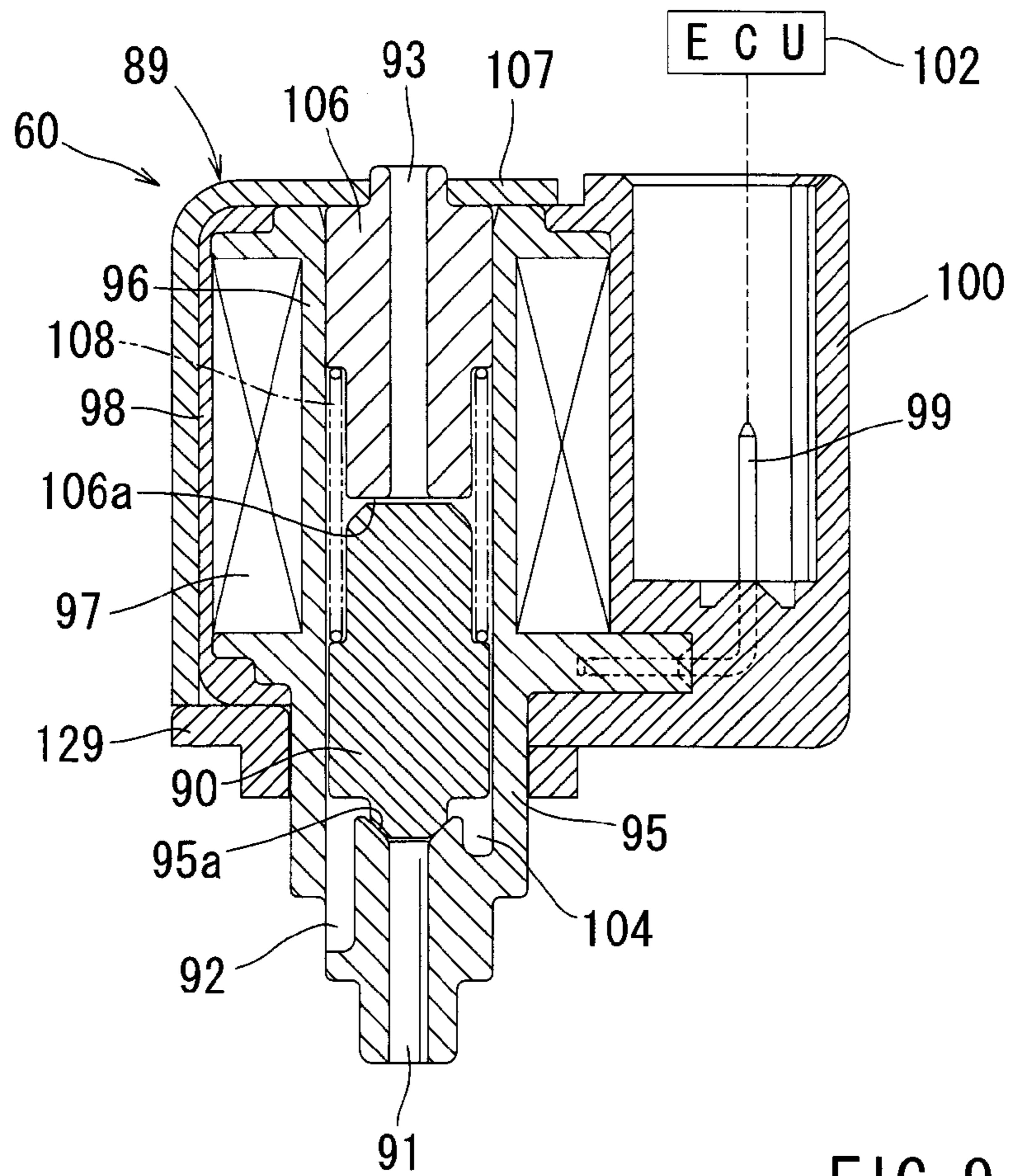


FIG. 9

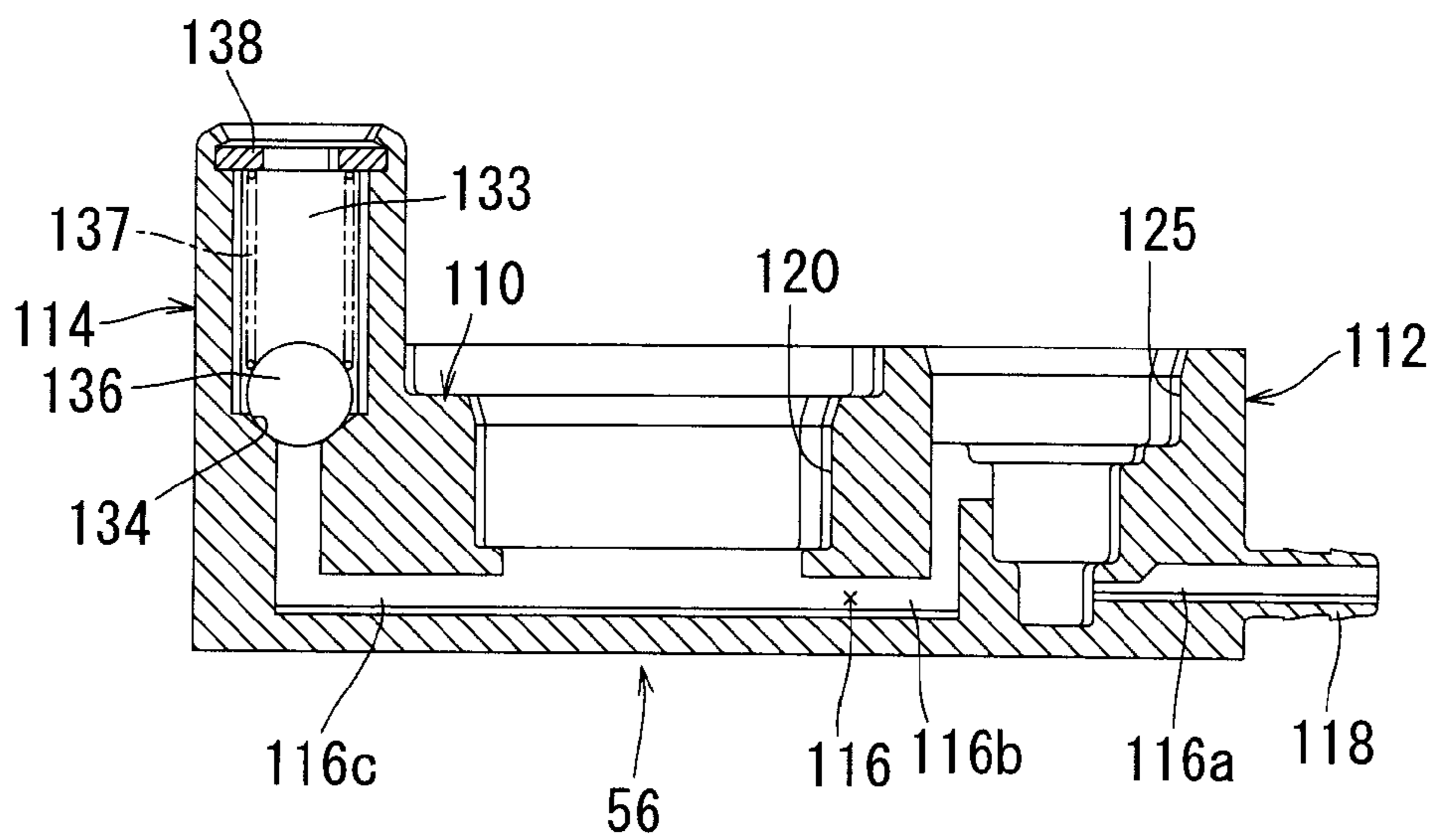


FIG. 10



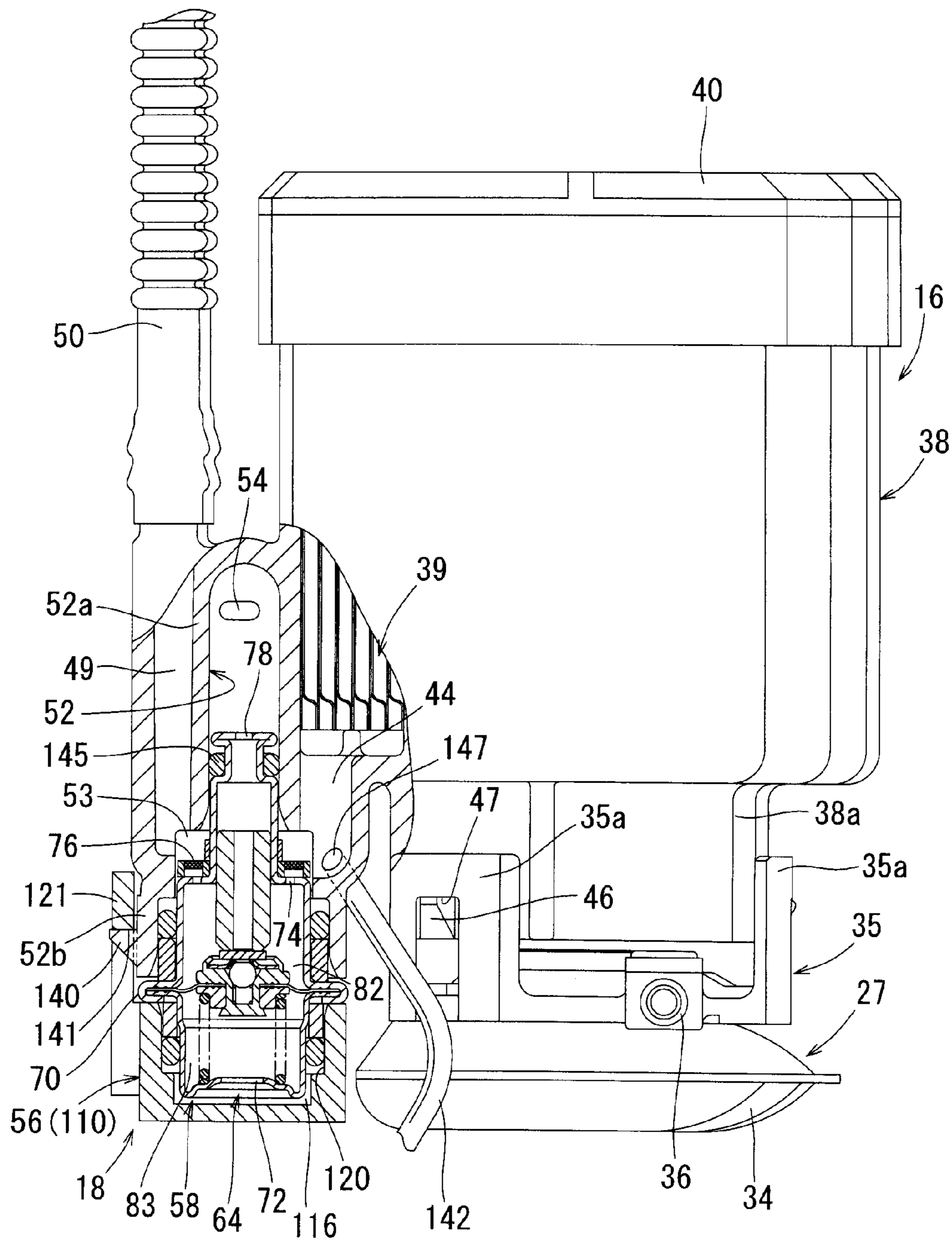


FIG. 11

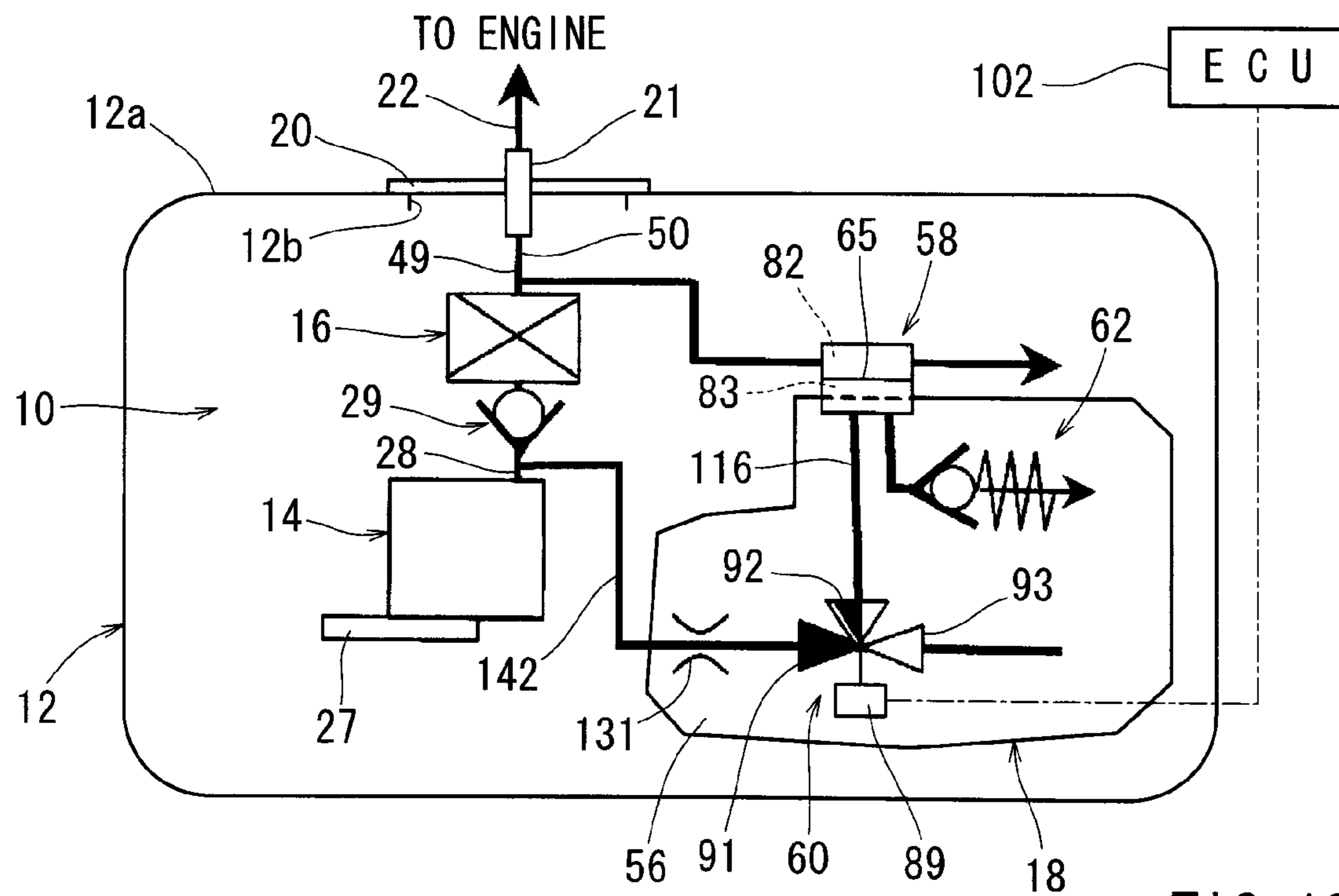


FIG. 12

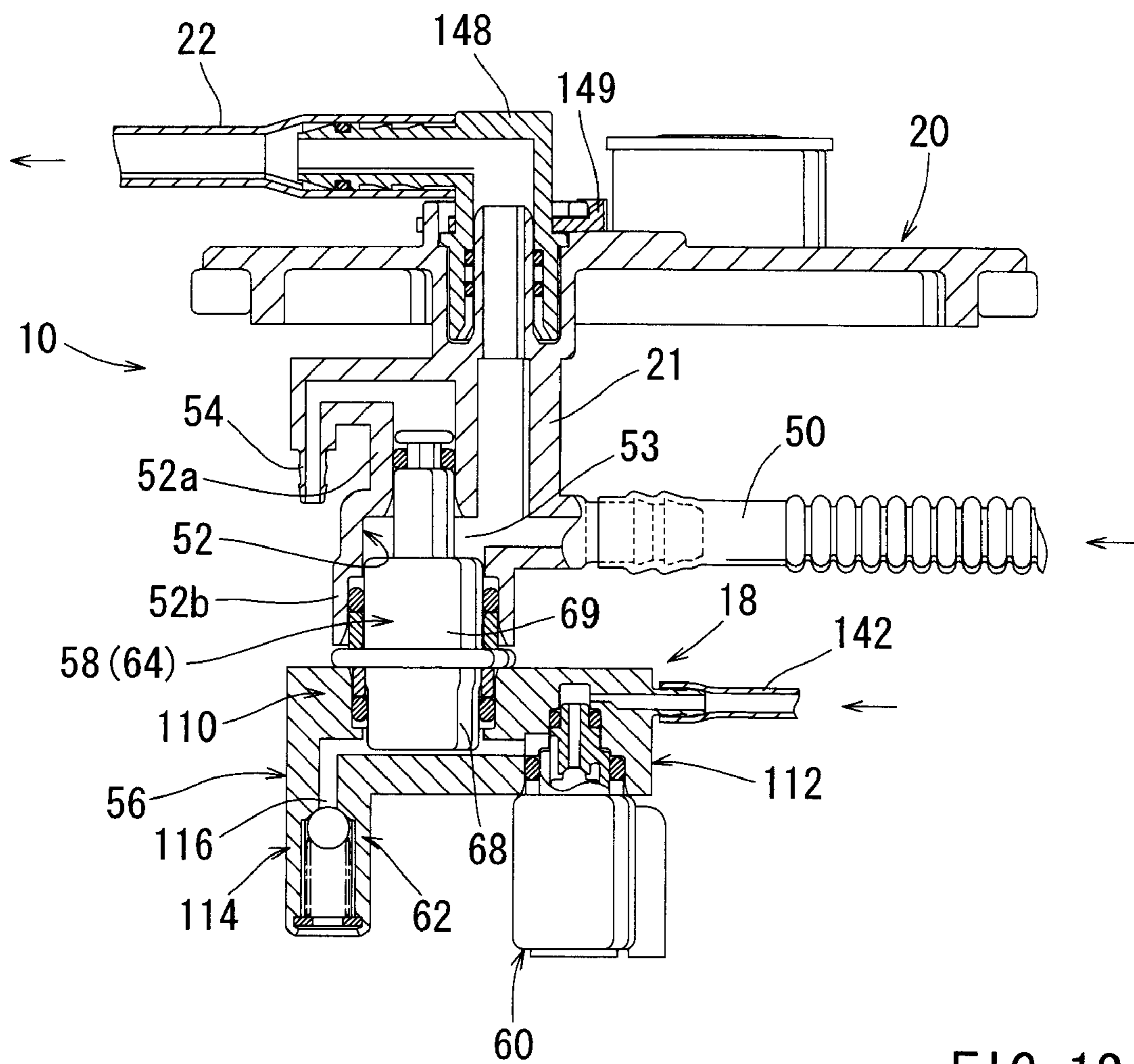


FIG. 13





## 1

## FUEL SUPPLY SYSTEMS

This application claims priority to Japanese patent application serial number 2008-212771, the contents of which are incorporated herein by reference.

## BACKGROUND OF THE INVENTION

The present invention relates to fuel supply systems mainly used for engines of vehicles.

A known fuel supply system will be described. FIG. 14 is a schematic structural view showing the known fuel supply system.

As shown in FIG. 14, in a fuel supply system 200, fuel in a fuel tank 201 is suctioned and pressurized due to a fuel pump 202, and then is transported through a feeding pipe 203 and is injected from each of injection valves 205 toward a combustion chamber of an internal combustion engine (hereafter called "engine"). A reflux control valve 224 (also called "on-off valve") is opened and closed depending on control signals from a control unit 229 such that pressure of the fuel (hereafter called "fuel pressure") supplied to the injection valves 205 can be switched between two levels, i.e., high pressure level and low pressure level. That is, when the reflux control valve 224 is opened during, for example, engine starting, the fuel is introduced into a control pressure chamber 208B of a pressure regulator 208, and fuel pressure in the control pressure chamber 208B increases. With this, fuel pressure in a pressure regulating chamber 208A of the pressure regulator 208 is increased, and fuel pressure in the feeding pipe 203 communicating with the pressure regulating chamber 208A is increased. This makes the pressure of fuel supplied to each injection valves 205 increase, so that atomization of injected fuel is enhanced, and startability of the engine is improved. In addition, when the reflux control valve 224 is closed after engine starting, introduction of fuel into the control pressure chamber 208B of the pressure regulator 208 is inhibited, and the fuel pressure in the control pressure chamber 208B decreases. With this, the fuel pressure in the pressure regulating chamber 208A is decreased, and the fuel pressure in the feeding pipe 203 is decreased. This makes the pressure of the fuel supplied to the each injection valve 205 decrease, so that a load, for example, on the fuel pump 202 can be reduced. The known fuel supply system is disclosed in, for example, Japanese Laid-Open Patent Publication No. 2001-90624.

In the known fuel supply system 200 (refer to FIG. 14), a fuel induction pipe 206 branched from the feeding pipe 203 is connected to the pressure regulating chamber 208A of the pressure regulator 208, and an upstream induction pipe 222A branched from the fuel induction pipe 206 is connected to the reflux control valve 224 (in particular, valve chamber). The reflux control valve 224 (in particular, valve chamber) is connected with the control pressure chamber 208B of the pressure regulator 208 via a downstream induction pipe 222B. The upstream induction pipe 222A and the downstream induction pipe 222B form a fuel passage for control pressure (hereafter called fuel passage) to the control pressure chamber 208B of the pressure regulator 208 and the reflux control valve 224, and are composed of piping members such as hose or pipe. Accordingly, the number of piping members used for the fuel passage and the number of assembly steps must be increased, resulting complicating the piping work. In addition, complex piping arrangement causes decrease of assembly property of the pressure regulator 208 and the reflux control valve 224 and decrease of sealing performance depending on the assembly property.

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Thus, there is a need in the art for an improved fuel supply system.

## SUMMARY OF THE INVENTION

One aspect according to a fuel supply system of the present invention includes a fuel pump for supplying fuel in a fuel tank to an engine, a pressure regulator and a three-way valve disposed in a valve chamber. The pressure regulator includes a pressure regulating chamber and a control pressure chamber and adjusts fuel pressure in the pressure regulating chamber depending on fuel pressure in the control pressure chamber. A control pressure passage for flowing the fuel to the control pressure chamber and the valve chamber is defined in a unit case.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic structural view showing a fuel supply system according to one aspect of the invention;

FIG. 2 is a partially sectional front view of the fuel supply system;

FIG. 3 is a cross-sectional view along line III-III in FIG. 2;

FIG. 4 is a cross-sectional view along line IV-IV in FIG. 2;

FIG. 5 is a cross-sectional view of a fuel pump;

FIG. 6 is a cross-sectional view showing a part of a filter case;

FIG. 7 is a cross-sectional side view of a control pressure regulation unit;

FIG. 8 is a cross-sectional view of a pressure regulator;

FIG. 9 is a cross-sectional view of a three-way valve;

FIG. 10 is a cross-sectional view of a unit case;

FIG. 11 is a partially sectional front view of a fuel supply system according to another aspect;

FIG. 12 is a schematic structural view of a fuel supply system according to another aspect;

FIG. 13 is a partially sectional front view of a fuel supply system according to another aspect; and

FIG. 14 is a schematic structural view of a fuel supply system known in the prior art.

## DETAILED DESCRIPTION OF THE INVENTION

Each of the additional features and teachings disclosed above and below may be utilized separately or in conjunction with other features and teachings to provide improved fuel supply systems. Representative examples of the present invention, which examples utilized many of these additional features and teachings both separately and in conjunction with one another, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skilled in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detailed description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative examples and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful embodiments of the present teachings.

One embodiment of a fuel supply system according to the present invention includes a fuel tank for storing fuel, a fuel pump, a pressure regulator, a control device, a changeover valve and a passage forming member. The fuel pump supplies



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the fuel in the tank to an engine. The pressure regulator has a pressure regulating chamber and a control pressure chamber divided by a movable partition, adjusts a fuel pressure in the pressure regulation chamber depending on pressure in the control pressure chamber, and discharges redundant fuel in the pressure regulation chamber. The fuel introduced into the pressure regulation chamber is the pressurized fuel after pressurization due to the fuel pump, whereas the fuel introduced into the control pressure chamber is the fuel after pressurization or being pressurized due to the fuel pump. The changeover valve is disposed in a valve chamber and selectively switches between an introduction of fuel and an introduction of air to the control pressure chamber of the pressure regulator depending on control by the control device. The passage forming member forms a control pressure passage for feeding the fuel to the control pressure chamber of the pressure regulator and the valve chamber for the changeover valve.

According to the above fuel supply system, the fuel in the fuel tank is suctioned and pressurized due to the fuel pump, and then is adjusted to a predetermined fuel pressure by the pressure regulator and is supplied to the engine. In addition, the changeover valve is controlled by the control device, and it is selectively switched between the induction of fuel and the induction of air to the control pressure chamber of the pressure regulator in order to change fuel pressure supplied to the engine.

Here, the control pressure passage for flowing the fuel to the control pressure chamber of the pressure regulator and the valve chamber of the changeover valve is formed in the passage forming member. Therefore, it is able to reduce the number of parts and the number of assembly steps as for piping members such as hose and pipe used for the fuel passage connected to control pressure chamber of the pressure regulator and the changeover valve.

According to another embodiment, the passage forming member supports a portion of the pressure regulator, which includes the control pressure chamber. Therefore, the passage forming member can work as a support member for the portion of the pressure regulator.

According to another embodiment, the pressure regulator and the changeover valve are assembled to the passage forming member from the same direction. Therefore, it is able to improve assembly property of the pressure regulator and the changeover valve to the passage forming member.

According to another embodiment, a relief valve controlling the fuel pressure in the control pressure chamber of the pressure regulator to a predetermined pressure is provided in the control pressure passage of the passage forming member. Therefore, it is able to control the fuel pressure in the control pressure chamber of the pressure regulator at the predetermined pressure due to the relief valve. In addition, the relief valve is disposed in the control pressure passage of the passage forming member, so that it is able to omit some piping members such as hose or pipe forming the fuel passage for the relief valve and to simplify a piping arrangement as for the fuel passage.

According to another embodiment, the changeover valve, the pressure regulator and the relief valve are sequentially disposed in the control pressure passage from an upstream side to a downstream side. Therefore, the fuel flowing in the control pressure passage of the passage forming member sequentially passes through the changeover valve, the pressure regulator and the relief valve, and then flows out of control pressure passage. Thus, it is able to prevent or reduce accumulation of the fuel in the control pressure passage.

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According to the other embodiment, at least two of the pressure regulator, the changeover valve and the relief valve are assembled to the passage forming member from the same direction. Therefore, it is able to improve assembly property of at least two of the pressure regulator, the changeover valve and the relief valve to the passage forming member.

Aspects of the invention will be described in reference to the drawings.

FIG. 1 is a schematic structural view showing a fuel supply system. FIG. 2 is a partially sectional front view. FIG. 3 is a cross-sectional view along line III-III in FIG. 2. FIG. 4 is a cross-sectional view along line IV-IV in FIG. 2.

As shown in FIG. 1, a fuel supply system 10, that can be mounted on a vehicle, supplies fuel (in a fuel tank 12) to an engine (in particular, an injector). The fuel supply system 10 has a fuel pump 14 disposed in the fuel tank 12, a fuel filter 16 and a control pressure regulation unit 18. An opening 12b formed in an upper plate 12a of the fuel tank 12 is closed with a set plate 20. The set plate 20 is provided with a fuel feeding pipe 21 communicating inside and outside of the fuel tank 12. In addition, a fuel feeding passage 22 communicating with the engine (in particular, the injector) is connected with the fuel feeding pipe 21 outside the fuel tank 12.

FIG. 5 is a cross-sectional view of fuel pump 14, which can be in-tank fuel pump integrated with a motor, including an electric motor 24 and an impeller pump 25 attached to a lower end of the motor 24. A fuel intake opening 26 for suctioning the fuel in the fuel tank 12 is formed at a lower side of the pump 25. The fuel intake opening 26 is connected with a suction filter 27 for filtering the fuel suctioned from the fuel tank 12 (refer to FIG. 1) into the fuel pump 14. A fuel discharge opening 28 for discharging the fuel in the motor 24 is provided at an upper surface of the motor 24. In addition, a check valve 29 preventing backflow of the fuel is provided in the fuel discharge opening 28 of the fuel pump 14.

In the fuel pump 14, when an impeller 30 of the pump 25 is rotated due to operation of the motor 24, the fuel in the fuel tank 12 is suctioned and pressurized, and then is discharged into the motor 24. The fuel discharged from the pump 25 into the motor 24 cools the inside of the motor 24, lubricates and cleans a rotating portion in the motor during flowing upward in the motor 24, and then is discharged from the fuel discharge opening 28. A vapor jet 32 for discharging vapor (bubble caused by vaporization of the fuel), which is included in the fuel during pressurization, from a pump passage 31 is mounted on a lower side of the pump 25. In addition, the vapor jet 32 corresponds to "vapor fuel discharge opening discharging the fuel including vapor (called "vapor fuel")" herein.

As shown in FIG. 2, the suction filter 27 has a filter member 34 formed in a bag shape and an attachment 35 mounted on an upper surface of the filter material 34. The attachment 35 is fitted with the lower surface of the pump 25 such that an inner space of the filter member 34 communicates with the fuel intake opening 26. The attachment 35 is provided with a hose connecting port 36 communicating with the vapor jet 32 of the fuel pump (refer to FIG. 5) and protruding forward (refer to FIG. 4). Here, the attachment 35 is adapted to be attached to a lower side of a filter case 38 (described later).

As shown in FIG. 2, the fuel filter 16 has the filter case 38 and a cylindrical tubular filter element 39 dividing an inner space of the case 38 into two chambers. An upper opening of the filter case 38 is closed with a filter cover 40. The filter case 38 has a fuel inlet (not shown) communicating with one chamber and a fuel outlet 44 communicating with the other chamber (refer to FIG. 2). The fuel pump 14 is supported such that the pump 14 passes through a central region of the filter



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case 38 (refer to FIG. 4). In addition, the fuel inlet of the filter case 38 communicates with the fuel discharge opening 28 of the fuel pump 14 (refer to FIG. 5).

The attachment 35 of the suction filter 27 is attached to the lower surface of the filter case 38, due to (for example) snap fitting. With respect to such snap fitting, at least one engaging projection 46, which is formed on an outer surface of a cylindrical tubular portion 38a protruding downwardly from a lower surface of the filter case 38, and at least one engaging hole 47, which is formed in attaching pieces 35a (two pieces are shown in FIG. 2) of the attachment 35 engaging with the outer cylindrical surface of the filter case 38, engage with each other due to elastic deformation of the attaching piece 35a.

As shown in FIG. 2, a fuel discharge passage 49 communicating with the filter case 38 and extending upwardly is formed at a lower right portion of the filter case 38. An upper end of the fuel discharge passage 49 and a lower end of the fuel feeding pipe 21 of the set plate 20 communicate with each other via a piping member 50 in the fuel tank 12 (refer to FIG. 1).

FIG. 6 is a cross-sectional view showing the main part of the filter case. A regulator receiving recess 52 in a cylindrical tubular shape opening at a bottom portion and closing at a top portion is formed between the fuel outlet 44 and the fuel discharge passage 49 of the filter case 38. The regulator receiving recess 52 is formed in the cylindrical tubular shape having two stepped portions. A communicating port 53, which communicates with the fuel outlet 44 and the fuel discharge passage 49 are formed on right and left sides of an lower end portion of an upper cylindrical portion 52a defining the regulator receiving recess 52. In addition, fuel ejection openings 54 radially (in a front and rear direction of a paper with respect to FIG. 6) passing through the upper cylindrical portion 52a at front and rear sides of an upper end portion of the upper cylindrical portion 52a.

FIG. 7 is a sectional side view of the control pressure regulation unit. As shown in FIG. 7, the control pressure regulation unit 18 has a unit case 56, a pressure regulator 58, a three-way valve 60 and a relief valve 62.

FIG. 8 is a cross-sectional view showing the pressure regulator. As shown in FIG. 8, the pressure regulator 58 is composed of a casing 64, a diaphragm 65 and a valve 66. The casing 64 is an outer shell of the pressure regulator 58 and is formed by engaging a case 68, which is positioned at a side of a control pressure chamber (lower side) and is formed in a cylindrical tubular shape opening upwardly and closed at a bottom portion, and a case 69, which is positioned at a side of a pressure regulating chamber (upper side) and is formed in a cylindrical tubular shape opening downwardly and closed at a top portion, due to swaging. Here, a flange 70 protruding from an outer circumferential surface of the casing 64 is formed due to swaging of both cases 68 and 69.

A communicating hole 72 opens at a bottom wall of the case 68 positioned at the side of the control pressure chamber. In addition, the case 69 at the pressure regulating chamber side is formed in a cylindrical shape having two stepped portions. A fuel feed opening 74 is formed in a stepped wall connecting a small diameter cylindrical portion 69a and a large diameter cylindrical portion 69b of the case 69. A ring-shape filter member 76 to be positioned on the stepped wall is fitted with the small diameter cylindrical portion 69a of the case 69. The filter member 76 can filter the fuel discharged from inside of the case 69 through the fuel feed opening 74. In addition, a fuel discharge hole 78 opens in an upper end wall of the case 69. An upper portion of a valve seat 80 in a

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cylindrical tubular shape is fixed within the small diameter cylindrical portion 69a of the case 69 due to press fitting.

The diaphragm 65 is supported from both sides thereof between the cases 68 and 69 and divides an inner space of the casing 64 into the pressure regulating chamber 82 at the upper side and the control pressure chamber 83 at the lower side. The diaphragm 65 is formed from a rubber like elastic material, and thus has flexibility. The diaphragm 65 corresponds to “movable partition” herein. In addition, a central portion of the diaphragm 65 is engaged with a support member 85 at an upper side and a spring receiving portion 86 at a lower side due to swaging.

The valve 66 is movably supported on the support member 85. When the valve 66 moves in an axial direction (vertical direction) due to flexural deformation of the diaphragm, a lower end of the valve seat 80 is opened and closed, so that communication between inside of the valve seat 80 and the pressure regulating chamber 82 can be allowed and blocked. Within the control pressure chamber 83, a valve spring 87 made of a coil spring is disposed between the bottom wall of the case 68 at the side of the control pressure chamber and the spring receiving portion 86. The valve spring 87 is biased in a direction that the valve 66 is seated on the valve seat 86, i.e., valve closing direction.

When a fuel pressure for pressing against the diaphragm 65 in the pressure regulating chamber 82 is lower than a pressing force against the diaphragm 65, that is elastic force of the valve spring 87 in the control pressure chamber 83, the valve 66 is moved upwardly due to the elastic force of the valve spring 87 and is seated on the valve seat 80. When the fuel pressure in the pressure regulating chamber 82 is higher than the elastic force of the valve spring 87, the valve 66 is moved downwardly due to flexural deformation of the diaphragm 65 and is removed away from the valve seat 80. This causes reduction of the fuel pressure in the pressure regulating chamber 82 to a predetermined value. In addition, when the fuel pressure in the pressure regulating chamber 82 reaches the predetermined value, the valve 66 is closed due to the elastic force of the valve spring 87.

FIG. 9 is a cross-sectional view showing the three-way valve. As shown in FIG. 9, the three-way valve 60 is an electrically-driven changeover valve and is configured such that communicating states and blocking states of a first port 91, a second port 92 and a third port 93 can be changed by moving a plunger 90 in an axial direction (vertical direction in FIG. 9) due to driving force of a solenoid portion 89. The solenoid portion 89 is configured by winding a solenoid coil 97 around a bobbin portion 96 formed on an upper portion of a valve body in a cylindrical tubular shape. The bobbin portion 96 and the solenoid coil 97 are fitted with a resin portion 98. A connector portion 100 in a socket shape surrounding a terminal 99 connected with the solenoid coil 97 is formed on the resin portion 98. The connector portion 100 is configured to be connected with a power feeding connector in a plug shape (not shown) from above. Power distribution to the solenoid coil 97 is controlled depending on control signals from an electronic control unit (ECU) 102. In addition, the three-way valve 60 corresponds to “changeover valve” herein.

A valve chamber 104 is formed in the valve body 95. The first port 91 and the second port 92 communicating with the valve chamber 104 are formed on a lower end portion. The first port 91 passes through the valve body 95 in the axial direction (vertical direction in FIG. 9) and opens at a lower surface of the valve body 95 and opens into the valve chamber 104. A valve seat 95a is formed around an upper opening portion of the first port 91. In addition, the second port 92



extends in the vertical direction and opens at an outer circumferential surface of the valve body **95** and opens into the valve chamber **104**.

A cylindrical member **106** in a cylindrical tubular shape is disposed within an upper portion of the bobbin portion **96** of the valve body **95**. The cylindrical member **106** is held by a magnetic plate **107** mounted on an upper surface of the valve body **95**. The third port **93** is defined by the cylindrical member **106** and passes through the cylindrical member **106** in the axial direction (vertical direction in FIG. 9). A valve seat **106a** is formed at a lower surface of the cylindrical member **106**. For convenience of explanation, the valve seat **106a** is referred to as “upper valve seat **106a**”, whereas the valve seat **95a** is referred to as “lower valve seat **95a**”. The plate **107** covers an outer circumferential surface of the resin portion **98**. A ring member **129** having magnetic properties and engaged with the valve body **95** is mounted on a lower surface of the resin portion **98**. A flange portion of the ring member **129** is attached to a lower portion of the plate **107** due to, for example, welding.

The plunger **90** is disposed in the valve chamber **104** of the valve body **95** so as to slidably move in the axial direction (vertical direction in FIG. 9). In addition, a gap having a predetermined length is configured between an inner circumferential wall of the valve chamber **104** of the valve body **95** and an outer circumferential surface of the plunger **90**. The lower valve seat **95a** and the upper valve seat **106a** are selectively opened and closed due to vertical movement of the plunger **90**. A valve spring **108** made of a coil spring is disposed between the plunger **90** and the cylindrical member **106**. The valve spring **108** is biased in a direction that the plunger is seated on the lower valve seat **95a**.

In the three-way valve **60**, when the solenoid coil **97** is not provided with the electric power (in an OFF state), the plunger **90** is pressed downwardly due to elastic force of the valve spring **108**. Thus, the plunger **90** is seated on the lower valve seat **95a**, and the first port **91** is closed. In this state, the plunger **90** is removed away from the upper valve seat **106a**, so that the third port **93** is opened. Therefore, the second port **92** and the third port **93** communicate with each other via the gap between the inner circumferential surface of the valve chamber **104** of the valve body **95** and the outer circumferential surface of the plunger **90**.

When the solenoid coil **97** is provided with the electric power (in an ON state), the plunger **90** is moved upwardly against the elastic force of the valve spring **108** due to magnetic force generated by provision of the electric power. Thus, the plunger **90** is seated on the upper valve seat **106a**, and the third port **93** is closed. In this state, the plunger **90** is removed away from the lower valve seat **95a**, so that the first port **91** is opened and communicates with the second port **92**.

The ECU **102** is a control unit composed of, for example, microcomputer. An input terminal of the ECU **102** is connected with a detecting device, e.g., a starting switch such as an ignition switch or a start switch of the engine. Whereas, an output terminal of the ECU **102** is connected with the solenoid coil **97** of the three-way valve **60**. In addition, the ECU **102** is configured to carry out on-off control of the solenoid coil **97** of the three-way valve **60** depending on operating state of the engine. For example, the ECU **102** is configured to put the solenoid coil **97** in the ON state during a predetermined period after starting process of the engine is started (the starting switch such as the ignition switch or the start switch is turned on), and to put the solenoid coil **97** in the OFF state after the elapse of the predetermined period. The ECU **102** corresponds to “control device” herein.

FIG. 10 is a cross-sectional view showing the unit case. As shown in FIG. 10, the unit case **56** includes a regulator support portion **110**, a three-way valve support portion **112** formed at one side (for example, front side (right side in FIG. 10)) of the regulator support portion **110**, and a relief valve support portion **114** formed on another side (for example, rear side (left side in FIG. 10)) of the regulator support portion **110**. The support portions **110**, **112** and **114** are formed in a line in a front-back direction (right and left direction in FIG. 10), and are close to each other. In addition, a control pressure passage **116** communicating with each of the support portions **110**, **112** and **114** is formed in the unit case **56**. One end (front end) of the control pressure passage **116** opens into a hose connecting port **118** formed on a front surface (right surface in FIG. 10) of the unit case **56**. The other end of the control pressure passage **116** opens upwardly at the relief valve support portion **114**. In addition, the unit case **56** corresponds to “passage forming member” herein.

A regulator engaging recess **120** in a cylindrical tubular shape opening upwardly and having a bottom is formed in the regulator support portion **110**. The control pressure passage **116** passes through a bottom portion of the regulator engaging recess **120** in the front-back direction (right and left direction in FIG. 10). As shown in FIG. 7, the case **68** at the side of the control pressure chamber of the casing **64** in the pressure regulator **58** (refer to FIG. 8) is fitted within the regulator engaging recess **120** from above. The flange portion **70** of the casing **64** is supported on an upper surface of the regulator support portion **110**. The communicating hole **72** of the pressure regulator **58** communicates with the control pressure passage **116**. An engaging piece **121** engaging with an outer circumference of a lower cylindrical portion **52b** defining a regulator receiving recess **52** of the filter case **38** protrudes above the regulator support portion **110** (refer to FIG. 2). An O-ring **122** and a ring-shape member **123** positioned above the O-ring **122** are disposed between an inner circumferential surface of the regulator engaging recess **120** and an outer circumferential surface of the case **68** at the side of the control pressure chamber (refer to FIG. 7). In addition, the case **68** at the control pressure chamber side corresponds to “portion at a control pressure chamber side”.

As shown in FIG. 10, a valve engaging recess **125** in a cylindrical tubular shape opening upwardly and having a bottom is formed in the three-way valve support portion **112**. The valve engaging recess **125** is formed in a stepped cylindrical tubular shape such that the control pressure passage **116** passes through a bottom portion of the valve engaging recess **125** in the front-back direction (right and left direction in FIG. 10). In particular, a downstream end of an upstream pathway **116a** of the control pressure passage **116**, which communicates with the hose connecting port **118**, opens concentrically in a bottom surface of the valve engaging recess **125**. Whereas, an upstream end of a downstream pathway **116b** of the control pressure passage **116**, which communicates with the regulator engaging recess **120**, opens in the inner circumferential surface of the valve engaging recess **125**.

As shown in FIG. 7, a lower portion of the valve body **95** protruding below the ring member **129** of the three-way valve **60** (refer to FIG. 9) is fitted within the valve engaging recess **125** from above. With this, the ring member **129** is supported on an upper surface of the three-way valve support portion **112**. The first port **91** of the three-way valve **60** communicates with the upstream pathway **116a** of the control pressure passage **116**. The second port **92** of the three-way valve **60** communicates with the downstream pathway **116b** of the control pressure passage **116**. A pair of O-rings **127** and **128**



and a protrusion formed on the ring member 129 are disposed between the inner circumferential surface of the valve engaging recess 125 and the outer circumferential surface of the valve body 95. A constricted portion 131 narrowing a downstream portion of the upstream pathway 116a is formed at an intermediate portion of the upstream pathway 116a of the control pressure passage 116. The constricted portion 131 limits the amount of the fuel introduced into the control pressure chamber 83 of the pressure regulator 58 through the control pressure passage 116 to a predetermined amount.

As shown in FIG. 10, a valve chamber 133 in a cylindrical tubular shape opening upwardly and having a bottom is formed in the relief valve support portion 114 of the unit case 56. A downstream end of a pathway 116c of the control pressure passage, which communicates with the regulator engaging recess 120, opens concentrically at a lower surface of the valve chamber 133. A taper-shape valve seat 134 expanding upwardly is formed at the downstream end of the pathway 116c. A spherical valve 136, a spring 137 made of a coil spring and a ring-shape stopper 138 are sequentially provided within the valve chamber from above. The spherical valve 136 can open and close the valve seat 134 due to its vertical movement. The spring 137 biases the spherical valve 136 in a closing direction (downwardly in FIG. 10). The stopper 138 is fixed within an upper opening of the valve chamber 133 due to swaging and supports the spring 137 in a compressed state.

The control pressure regulation unit 18 (refer to FIG. 7) is assembled on the filter case 38 (refer to FIG. 6) of the fuel filter 16 as described below. That is, as shown in FIG. 2, the regulator support portion 110 of the unit case 56 of the control pressure regulation unit 18 is attached to the lower cylindrical portion 52b of the regulator receiving recess 52 of the filter case 38 due to snap fitting. Here, such snap fitting is configured by an engaging projection 140 formed on an outer circumferential surface of the lower cylindrical portion 52b of the regulator receiving recess 52 of the filter case 38 and an engaged hole 141 formed in the engaging piece 121 of the regulator engaging recess 120, which is engaged with the outer circumferential surface of the lower cylindrical portion 52b, and engaged with the engaging projection 140 due to elastic deformation of the engaging piece 121 (refer to FIG. 4).

When the control pressure regulation unit 18 is assembled on the filter case 38, the case 69 at the pressure regulating chamber side of the pressure regulator 58 is fitted within the regulator receiving recess 52 of the filter case 38. Thus, as shown in FIG. 3, the casing 64 of the pressure regulator 58 is supported from both sides thereof between the regulator engaging recess 120 of the regulator support portion 110, and the flange portion 70 of the casing 64 is supported from both sides thereof between the lower cylindrical portion 52b of the regulator receiving recess 52 and the regulator support portion 110. In addition, the fuel feed opening 74 of the case 69 at the pressure regulating chamber side of the pressure regulator 58 communicates with the communicating port 53 of the filter case 38 via the filter member 76. The fuel discharge hole 78 of the case 69 at the pressure regulating chamber side communicates with inside of the upper cylindrical portion 52a of the regulator receiving recess 52.

As shown in FIG. 4, the hose connecting port 36 of the suction filter 27 and the hose connecting port 118 of the unit case 56 communicate with each other via a fuel feed hose 142. As shown in FIG. 3, an O-ring 143 and a ring member 144 positioned below the O-ring 143 are disposed between the inner circumferential surface of the lower cylindrical portion

52b of the regulator receiving recess 52 and an outer circumferential surface of the large diameter cylindrical portion 69b of the pressure regulating chamber case 69. An O-ring 145 is disposed between an inner circumferential surface of the upper cylindrical portion 52a of the regulator receiving recess 52 and an outer circumferential surface of the small diameter cylindrical portion of the case 69 at the pressure regulating chamber side. The fuel supply system 10 is disposed in the fuel tank 12 because, for example, the filter case 38 is supported on the set plate 20.

Operation of the fuel supply system 10 will be described. In FIG. 1, when the engine starts, the fuel pump 14 works so that the fuel in the fuel tank 12 is suctioned through the suction filter 27, is pressurized due to the fuel pump 14, and then is discharged from the fuel discharge opening 28 (refer to FIG. 5). The pressurized fuel, which has been discharged, is filtered by the filter element 39 of the fuel filter 16 (refer to FIG. 2), and then flows from the fuel outlet 44 of the filter case 38 (refer to FIG. 4) to the communicating port 53 of the regulator receiving recess 52. After that, the pressurized fuel is supplied to the engine, i.e., the injector through the fuel discharge passage 49, the piping member 50, the fuel feeding pipe 21 (refer to FIG. 1) and fuel feeding passage 22, and is injected into a combustion chamber of the engine from the injector. With this, a part of the fuel flowing through the communicating port 53 of the filter case 38 (refer to FIG. 2) is introduced into the pressure regulating chamber 82 through the filter member 76 of the pressure regulator 58 and the fuel feed opening 74 (refer to FIG. 3).

When the solenoid coil 97 of the three-way valve 60 is provided with the electric power due to the control signals from the ECU 102 with starting of engine operation, the first port 91 and the second port 92 communicate with each other, and the third port 93 is blocked. In this state, the fuel discharged from the vapor jet 32 of the fuel pump 14 (refer to FIG. 5), that is partially pressurized fuel, is introduced from the hose connecting port 36 of the suction filter 27 (refer to FIG. 4) into the control pressure passage 116 of the unit case 56 (refer to FIG. 3) through the fuel feed hose 142. When the fuel introduced into the control pressure passage 116 flows into the control pressure chamber 83 of the pressure regulator 58, fuel pressure in the control pressure chamber 83 increases. At this time, the valve 66 of the pressure regulator 58 sits on the valve seat 80, so that fuel pressure in the pressure regulating chamber 82 increases furthermore. When the fuel pressure in the pressure regulating chamber 82 of the pressure regulator 58 becomes higher than that of the control pressure chamber 83, the diaphragm 65 is bent toward the control pressure chamber 83, and the valve 66 is moved away from the valve seat 80. Accordingly, the fuel in the pressure regulating chamber 82 is discharged into the upper cylindrical portion 52a of the regulator receiving recess 52 of the filter case 38 through the valve seat 80, the small diameter cylindrical portion 69a of the case 69 at the control pressure chamber side, and the fuel discharge hole 78. In addition, the fuel discharged into the upper cylindrical portion 52a is ejected into the fuel tank 12 through the fuel ejection opening 54. When the fuel pressure in the pressure regulating chamber 82 decreases, the diaphragm 65 is bent toward the pressure regulating chamber 82, and the valve 66 is seated on the valve seat 80. In this way, the fuel pressure in the pressure regulating chamber 82, that is the fuel pressure supplied to the engine, is adjusted to higher pressure than steady pressure, for example, to about 600 kPa.

As described previously, the fuel pressure supplied to the engine is adjusted to the pressure higher than the steady pressure due to the pressure regulator 58, so that atomization



of the fuel injected by the injector can be enhanced, and startability of the engine can be improved. The ON state of the three-way valve **60** is kept during a period from the time that the engine starts (the starting switch such as ignition switch or start switch is turned on) to the time that the predetermined period has been passed after completion of engine starting.

In addition, the pressure of the fuel introduced into the control pressure chamber **83** of the pressure regulator **58** is controlled to a predetermined pressure due to the relief valve **62**. That is, when the fuel pressure in the control pressure chamber **83** becomes higher than the elastic force of the spring **137**, the spherical valve **136** is moved away from the valve seat **134** against the elastic force of the spring **137**, and the fuel in the control pressure chamber **83** is released through the valve chamber **133**, so that the fuel pressure in the control pressure chamber **83** decreases to a predetermined pressure. When the fuel pressure in the control pressure chamber **83** reaches a predetermined pressure, the spherical valve **136** is seated on the valve seat **134** due to the elastic force of the spring **137**. Accordingly, the fuel pressure in the control pressure chamber **83** of the pressure regulator **58** is controlled to the predetermined pressure.

When the solenoid coil **97** of the three-way valve **60** is not provided with the electric power depending on the control signals from the ECU **102**, the first port **91** of the three-way valve **60** is blocked, whereas the second port **92** and the third port **93** communicate with each other. In this state, the fuel in the upper pathway **116a** of the control pressure passage **116** of the unit case **56** is restricted to flow into the lower pathway **116b**, i.e., the control pressure chamber **83** of the pressure regulator **58**. With this, air is introduced into the control pressure chamber **83**, that is, the control pressure chamber **83** is opened to the atmosphere. Therefore, pressure acting on the diaphragm **65** in the control pressure chamber **83** is caused by only the elastic force of the valve spring **87**. Accordingly, the fuel pressure in the pressure regulating chamber **82** of the pressure regulator **58**, that is, pressure of the fuel supplied to the engine is adjusted to the steady pressure, for example about 400 kPa.

As described previously, the pressure of the fuel supplied to the engine is adjusted to the steady pressure due to the pressure regulator **58** in order to reduce load on, for example, the fuel pump **14**. The ON state of the three-way valve **60** corresponds to “high pressure state” herein, and the OFF state of the three-way valve **60** corresponds to “steady pressure state” herein.

With respect to the fuel supply system **10** described previously, the fuel in the fuel tank **12** is suctioned into and pressurized by the fuel pump **14**, and then is adjusted to a predetermined pressure by the pressure regulator **58** and supplied to the engine. In addition, the three-way valve **60** is controlled due to the ECU **102**, and the fuel and the air are selectively switched for being supplied to the control pressure chamber **83** of the pressure regulator **58**, so that the pressure of the fuel supplied to the engine can be altered.

The control pressure passage **116** for feeding the fuel to the control pressure chamber **83** of the pressure regulator **58** and the valve chamber **104** of the three-way valve **60** is formed in a single member for forming passage, that is the unit case **56**. Therefore, the number of members and the number of assembly steps as for piping members such as hose or pipe used for the control pressure chamber **83** of the pressure regulator **58** and the three-way valve **60** can be reduced, and piping arrangement can be simplified. Thus, assembly property of the pressure regulator **58** and the three-way valve **60** to the unit case **56** and sealing property according to such assembly can be improved.

The controlled pressure in the control pressure chamber **83** of the pressure regulator **58** is more stabilized compared with a case that piping members such as hose or pipe are used, so that regulation ability of the pressure regulator **58** can be improved. The pressure regulator **58**, the three-way valve **60** and the relief valve **62** are disposed in a line in a front-back direction (right and left direction in FIG. 3), so that the control pressure regulation unit **18** and consequently the fuel supply system **10** can be configured more compactly. The pressure regulator **58** and the three-way valve **60** can be located close to each other, so that volume of the fuel passage can be reduced, and the reactivity to pressure can be improved.

The unit case **56** supports the case **68** at the control pressure chamber side of the casing **64** of the pressure regulator **58**. In particular, the unit case **56** has a regulator support portion **110** supporting the case **68** at the control pressure chamber side of the casing **64** of the pressure regulator **58**. Therefore, the unit case **56** can also work as a member supporting the case **68** at the control pressure chamber side of the pressure regulator **58**.

The pressure regulator **58** and the three-way valve **60** are assembled to the unit case **56** from the same direction (from above in FIG. 3). Therefore, assembly property of the pressure regulator **58** and the three-way valve **60** to the unit case **56** can be improved.

The relief valve **62** controlling the fuel pressure in the control pressure chamber **83** of the pressure regulator **58** to a predetermined pressure is provided in the control pressure passage **116** of the unit case **56** (FIG. 3). Accordingly, the fuel pressure in the control pressure chamber **83** of the pressure regulator **58** can be controlled to a predetermined pressure due to the relief valve **62**. In addition, the relief valve **62** is provided in the control pressure passage **116** of the unit case **56**, so that piping members such as hose or pipe forming the fuel passage to the relief valve **62** can be omitted, and piping arrangement for the fuel passage can be simplified.

The three-way valve **60**, the pressure regulator **58** and the relief valve **62** are sequentially disposed in the control pressure passage **116** of the unit case **56** from an upstream side to a downstream side (FIG. 3). Therefore, the fuel flowing in the control pressure passage **116** of the unit case **56** sequentially passes through the three-way valve **60**, the pressure regulator **58** and the relief valve **62**, and then is discharged from the control pressure passage **116**, so that the control pressure passage **116** does not have any dead-end portion. Accordingly, it is able to prevent or reduce stagnation, i.e., accumulation of the fuel in the control pressure passage **116**.

Three members, i.e., the pressure regulator **58**, the three-way valve **60** and the relief valve **62** are mounted on the unit case **56** from the same direction (from above in FIG. 3). Therefore, assembly property of the pressure regulator **58**, the three-way valve **60** and the relief valve **62** to the unit case **56** can be improved. In addition, it is only necessary to configure such that at least two of the pressure regulator **58**, the three-way valve **60** and the relief valve **62** are assembled to the unit case **56** from the same direction.

Another aspect that is a modified version of the first will be described. Only modified portions will be described, and redundant explanation will be omitted. FIG. 11 is a partially sectional front view of the fuel supply system.

As shown in FIG. 11, in this aspect, an upstream end of the fuel feed hose **142** in the first aspect (refer to FIG. 1) is connected to a hose connecting hole **147** formed in a wall of the pathway between the fuel outlet **44** of the filter case **38** and the communicating port **53** instead of the hose connecting port **36** of the suction filter **27**. That is, it is configured that a part of the fuel discharged from the fuel outlet **44** of the filter



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case **38** (pressurized fuel) is introduced into the control pressure passage **116** of the unit case **56** through the fuel feed hose **142**.

A aspect will be described. This aspect is a modified version of the first aspect. Only modified portions will be described, and redundant explanation will be omitted. FIG. **12** is a schematic structural view showing the fuel supply system.

As shown in FIG. **12**, in this aspect, the upstream end of the fuel feed hose **142** in the first aspect (refer to FIG. **1**) is connected to the fuel discharge opening **28** of the fuel pump **14** instead of the hose connecting port **36** of the suction filter **27**. That is, it is configured that a part of the fuel discharged from the fuel discharge opening **28** of the fuel pump **14** (pressurized fuel) is introduced into the control pressure passage **116** of the unit case **56**.

Another aspect will be described. This aspect corresponds to the first aspect partially modified, so that only modified portions will be described, and redundant explanation will be omitted. FIG. **13** is a partially sectional front view showing the fuel supply system.

As shown in FIG. **13**, in this aspect, the regulator receiving recess **52** in the first aspect (refer to FIG. **3**) is formed in the set plate **20** instead of the filter case **38**. In addition, the fuel feeding pipe **21** is formed in an L-shape at a lower surface of the set plate **20**. A laterally extending end portion of the fuel feeding pipe **21** is connected with the piping member **50**. At an upper surface of the set plate **20**, an L-shape feed pipe **148** is rotatably connected to an upper end of the fuel feeding pipe **21** such that the feed pipe **148** is prevented from detaching from the upper end of the fuel feeding pipe **21** due to a clip **149**. This feed pipe **148** is connected with the fuel feeding passage **22**.

The regulator receiving recess **52** in a cylindrical tubular shape opening at a lower side is formed in one side portion (right side portion in FIG. **13**) of the fuel feeding pipe **21**. The communicating port **53** of the regulator receiving recess **52** communicates with the fuel feeding pipe **21**. In addition, an upper end of the upper cylindrical portion **52a** of the regulator receiving recess **52** is formed in a reverse U-shape, and its lower end corresponds to the fuel ejection opening **54**.

In the unit case **56** of the control pressure regulation unit **18**, the three-way valve **112** and the relief valve support portion **114** are configured upside down compared with the first embodiment, and the two members, i.e., three-way valve **60** and the relief valve **62** are assembled to the unit case **56** from the same direction (from below in FIG. **13**). Therefore, it is able to improve assembly property of the three-way valve **60** and the relief valve **62** to the unit case **56**.

The present invention is not limited to the descriptions above, and can be modified without departing from the spirit and the scope of the invention. For example, the upstream end of the fuel feed hose **142** can be connected to a second fuel discharge opening formed in addition to the fuel discharge

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opening **28** of the fuel pump **14**. In addition, the upstream end of the fuel feed hose **142** can be connected to a second vapor jet formed in addition to the vapor jet **32** of the fuel pump **14**. That is, in a case that a part of the pressurized fuel or the partially pressurized fuel due to the fuel pump **14** is introduced into the control pressure chamber **83** of the pressure regulator **58**, the fuel can be introduced from any portion of the fuel pump **14**.

The invention claimed is:

1. A fuel supply system comprising:

- a fuel tank for storing fuel;
- a fuel pump supplying the fuel in the fuel tank to an engine;
- a pressure regulator having a pressure regulating chamber and a control pressure chamber divided by a movable partition, adjusting fuel pressure in the pressure regulation chamber depending on pressure in the control pressure chamber, and discharging redundant fuel in the pressure regulation chamber, wherein the fuel introduced into the pressure regulation chamber is the pressurized fuel after pressurization due to the fuel pump, and wherein the fuel introduced into the control pressure chamber is the fuel after pressurization or being pressurized due to the fuel pump;
- a control device;
- a changeover valve disposed in a valve chamber and selectively switching between an introduction of fuel and an introduction of air to the control pressure chamber of the pressure regulator depending on control by the control device; and
- a passage forming member forming a control pressure passage for feeding the fuel to the control pressure chamber of the pressure regulator and the valve chamber for the changeover valve.

2. The fuel supply system as in claim 1, wherein the passage forming member supports a portion including the control pressure chamber of the pressure regulator.

3. The fuel supply system as in claim 2, wherein the pressure regulator and the changeover valve are assembled to the passage forming member from the same direction.

4. The fuel supply system as in claim 3, further comprising a relief valve controlling the fuel pressure in the control pressure chamber of the pressure regulator to a predetermined pressure and disposed in the control pressure passage.

5. The fuel supply system as in claim 4, wherein the pressure regulator, the changeover valve and the relief valve are sequentially disposed in the control pressure passage from an upstream side to a downstream side.

6. The fuel supply system as in claim 5, wherein at least two of the pressure regulator, the changeover valve and the relief valve are assembled to the passage forming member from the same direction.

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